FIELD EXPERIMENT ON FERTILIZER APPLICATION IN CITRUS ORCHARDS

(First Report)

by

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Citrus industry in Taiwan has been developing gradually after the war, and the export of citrus fruits to Canada, Singapore, Korea and Philippine etc. in recent years has been increasing. This indicates the possibility for citrus to be a promissing crop. It is estimated that the annual production of citrus fruits in Taiwan at present is about 35,000 tons and the acreage of citrus orchard is about 5,800 ha.[1] which is expected to increase yearly.

Plentiful citrus harvest in an unit area hinges much on the technical management of the orchard, in which fertilizer practice plays an equally important role as pest and disease control and other cultivation techniques. We are frequently to find unreasonable fertilization at citrus orchards affecting its fruit yield and quality. However, the lack of experimental data on citrus fertilization caused by the difficulties involved in the experimentation of perennial crop make the farmers poorly provided with knowledge in using chemical fertilizers for its production, consequently the fertilizer allocation[2] for citrus conducted by the government seems not ideal.

To meet the demand mentioned above, this experiment has been undertaken since January, 1958, which will provide the optimum fertilizer ratio for soils with similar conditions to this experiment, and at the same time the effect of trace elements on citrus will also be clarified. Furthermore, by a long term experiment the effect of fertilizer upon fruit quality and storage will be acertained. Ponkan variety which is the most favourable one among citrus crops was selected as an object crop and field experiments were laid out at Shinpu and Yuanlin, representative of its production in Taiwan.

METHOD OF EXPERIMENT

1) **Experimental treatments:**

Fertilizer treatments are shown in Table 1, using ammonium sulphate, calcium superphosphate, potassium chloride as N, P, K sources respectively. As the treatments were designed to determine the deficiency of N, P, K in the soils as well as the effects of trace elements, the amount of fertilizers applied were actually more than sufficient. The amount of nitrogen was estimated on the basis of the fertilizer practice made by the local farmers as shown in Table 2.

Table 1. Experimental treatments

Name of plot	Treatment
a. PK	No N but P,K are applied
b. NK	No P but N,K are applied
c. NP	No K but N,P are applied
d. NPK	N, P, K are applied (check plot)
e. NPK & T. E.	N, P, K, Mg application and trace elements spraying

Note: 1. At Yuanlin experimental locality, 1.2kg of soybean cake per tree per year at all plots was applied in January in addition to the chemical fertilizers according to the local conventional practice.

2. In the treatment e, two kinds of trace elements, i. e. zinc and manganese were applied by foliage spray twice a year in May and September, using 0.5% solution of Zn SO_4 and $MnSO_4$. In addition, one pound of $MgSO_4$ per tree was applied in January every year.

Table 2. Amount of fertilizer applied

Locality	N	P_2O_5	K_2O
Shinpu orchard	300 kg/ha 600 g/tree	200 kg/ha 400 g/tree	250 kg/ha 500 g/tree
Yuanlin orchard	400 kg/ha 800 g/tree	250 kg/ha 500 g/trre	300 kg/ha 600 g/tree

Note: It was estimated on the basis of 500 trees per ha.

Fertilizers were applied in bands by hoeing ditchs up to a depth of 2 or 3 inches at both sides of tree trunk. Broadcasting is also an common practice in some orchards, but band placement were made all the time in this trial. The amount of fertilizers per tree were measured accurately by suitable vesseles.

2) **Experimental design and locality:**

Three localities for field trials were set out where the growth condition and tree age of citrus were uniform. One place is in Yuanlin town and two places in Hsinpu town as shown in Table 3.

Table 3. Localities of experiments

Chawmen, Hsinpu	(20 year old tree of citrus ponkan grove)
Taping, Hsinpu	(18 year old tree of citrus ponkan grove)
Yuanlin	(9 year old tree of citrus ponkan grove)

Randomized block was adopted with five replications in all experimental localities except in Taping where only four replications were permissible. Each plot consists of four experimental trees with one guard tree placed between two neighbouring plots.

It was reported by Pearce[3] that eight trees provide a more effective plot size for citrus experimentation owing to the fact that the more variation is involved in

the individual tree than in its position. However, as no adequate field is available to accommodate a large number of such plots, a compromise was made to give four trees for an unit plot.

3) **Time and proportion of ferilizer dessing:**

Most of the citrus growers applied chemical fertilizers twice per year in January and May and night soils several times according to their conventional practice. A proper fertilization is shown in Table 4 as recommended by Yakujitera[4] on which this experimental desighn was based.

Table 4. Time and proportion of fertilizer application

	N	P_2O_5	K_2O_5
January	50%	40%	30%
May	25%	40%	50%
August	25%	20%	20%

4) **Items invesigatted:**

A. Field records; Records were taken on fruit yields and their number

B. Leaf analysis;

Method of sampling: 20–30 matured leaves from every single tree which are at the position of 3rd and 4th leaves from the apex of twigs were taken, and the leaves from the same treatment in two blocks were combined to make a composite sample for chemical analysis. (I & II blocks, III & IV blocks, two replications) Times of leaf sampling were March, May, June, August and November.

Analytical method: Leaf sample was prepared according to Piper[5] and analysed on N, P, and K, i.e. Micro-Kjeldahl method for N, Molybdenum-blue method for P[6] and flame photometric method for K[7].

Soilt test: Soil samples were taken before fertilizer dressing and total N, available P and K, organic matter content, texture, and pH were determined.

RESULTS AND DISCUSSION

Soil Conditions

The soil conditions of Yuanlin experimental locality is quite different in comparison with that of Hsinpu. The former is slate alluvial soil with specific characters of paddy fields, such as high underground water level, (40–50cm in summer season and 70–80cm in winter season), fine texture, high fertility and neutral reaction, while the later is yellowish brown latosol which is developed on rolling hills and the parent materials are sandstone and shale. It is characterized by relatively dry condition, low fertility, coarse texture and acid in reaction. The description of the soils is shown as follows.

Table. 5. Chemical and physical properties of soils

Location	Depth	pH	N%	O.M.%	Ava. P kg/ha	Ava. K kg/ha	Texture	Clay%	Silt%	Sand%
Yuanlin	0-15cm	7.1	0.126	1.32	12	180	Si. L.	18	62	20
	15-40cm	7.2	0.083	0.96	12	160	C. L.	31	48	21
Chawmen, Hsinpu	0-15cm	5.3	0.092	0.51	7	70	S. L.	11	30	59
	15-40cm	5.3	0.052	0.31	5	70	S. L.	10	28	62
Taping, Hsinpu	0-15cm	5.5	0.075	0.57	7	70	S. L.	15	32	53
	13-40cm	5.2	0.048	0.49	7	50	S. L.	18	28	54

The soil analytical works were made by the routine methods at this laboratory, e. g. pH: glass electrode pH meter, Total N: Kjeldahl method, Organic matter content: Potassium dicromate titration, Available P & K: Peach and English's metod, Mechanical analysis: Hydrometer method etc.

Effects on Yields

The data of fruit yields in the first year trial at three localities are show in Table 6, 7 and 8. The plot which received complete fertilizer of three elements was taken as a check. According to the statistical analysis, the effects of treatments were found to be insignificant. However, the adverse effect induced from lacking either N or K could be perceived. In other words, the application of N and K in combination seemed to increase the fruit yields in all the experimental orchards. More time will be needed to detect if a significant trend is developing in those orchards. But judging from the result of the first year trial, nitrogen will be undoubtedly expected as the most essential element effecting fruit yield, and potash will come to the next. The effect of phosphate is still obscure.

Table 6. Fruit yields in Chawmen orchard kgs/plot (4 trees)

Treatment/Block	I	II	III	IV	V	Total	Index
a. PK	213.7	223.4	287.9	156.7	240.6	1,122.4	89
b. NK	296.7	278.3	326.0	217.6	271.3	1,389.9	111
c. NP	176.4	262.5	313.6	288.8	118.5	1,159.7	92
d. NPK	311.7	211.0	182.4	312.1	238.7	1,255.8	100
e. NPK with T. E.	300.0	190.7	282.7	262.5	240.8	1,276.7	102

L.S. D. among treatments, N. S.

Table 7. Fruit yields in Taping orchard kgs/plot (4 trees)

Treatment/Block	I	II	III	IV	Total	Index
a. PK	51.0	111.1	120.3	68.4	350.4	86
b. NK	135.6	73.9	128.9	119.2	457.6	112

c. NP	87.5	67.0	80.3	57.8	292.6	71
d. NPK	150.7	49.2	75.1	134.7	409.7	100
e. NPK with T. E.	160.7	140.2	55.1	85.1	441.1	108

L. S. D. among treatments, N. S.

Table 8. Fruit yields in Yuanlin orchard kgs/plot (4 trees)

Treatment/Block	I	II	III	IV	V	Total	Index
a. PK	141.5	220.2	174.4	13.7	28.4	578.2	66
b. NK	146.0	247.4	366.8	54.4	35.1	849.6	87
c. NP	218.1	283.1	37.9	56.6	55.8	671.5	77
d. NPK	257.3	276.9	244.2	41.2	53.2	872.7	100
e. NPK with T. E.	156.4	234.6	202.0	51.5	150.1	794.5	91

L. S. D. among treatments, N. S.

Table 9, 10 and 11 presented in below are the mean yields and number of fruits per tree and the mean weight of unit fruit. It also shows that nitrogen and potash are the evident factors effecting on yields and number of fruits. The effect of fertilizers upon the weight of unit fruit was not so apparent in those orchards except in Yuanlin where the weight of fruit was decreased considerably by the unfertilization of nitrogen. In general, the size of fruit was the largest in Yuanlin, the medium in Chawmen and the smallest in Taping. The water content of soil may be considered as a main factor for this difference, e. g. Yuanlin orchard producing the Largest fruit size had the highest water content due to its paddy field character, Chawmen orchard situated in a humid valley produced the medium size, and Taping orchard located in the most arid soil condition had the smallest size. It is expected that the experimental treatments may influence not only upon the yields but also the fruit size after a long term trial.

Table 9. Yields of fruits per tree (kgs)

Treatment/Location	Chawmen	Taping	Yuanlin	Mean	Index
a. PK	56.12	21.92	28.41	35.48	81
b. NK	69.49	28.58	42.48	46.85	106
c. NP	57.99	18.38	33.58	36.62	83
d. NPK	62.79	25.60	43.64	44.01	100
e. NPK with T. E.	63.83	27.57	39.73	43.71	99

Table 10. Number of fruits per tree

Treatment/Location	Chawmen	Taping	Yuanlin	Mean	Index
a. PK	308	138	141	196	85
b. NK	382	189	173	248	108

c. NP	308	103	142	184	80
d. NPK	335	170	184	229	100
e. NPK with T. E.	345	164	174	227	99

Table 11. Average weight per fruit (gs)

Treatment/Location	Chawmen	Taping	Yuanlin	Mean	Index
a. PK	182	159	201	180	94
b. NK	181	150	244	192	100
c. NP	188	177	235	200	104
d. NPK	187	150	237	191	100
e. NPK with T. E.	184	167	228	193	101

The use of chemical sources of nitrogen has increased postwar as compared with that of concentrated organic sources such as soybean cake, peanut cake, fish meal etc. which are used at present extensively as feed for livestock and their prices are accordingly much expensive. Nevertheless, the growers in yuanlin still use them more or less now owing to its high intensive cultivation. Due to this reason, 1.2 kg of soybean cake per tree per year in all plots were applied in Yuanlin experimental orchard, but none was applied in Hsinpu orchards where citrus trees are planted on hillsides in a comparatively extensive way. The amount of chemical nitrogen dressed in Yuanlin reached as much as 800 gs per tree excluding the organic nitrogen, whereas in Hsinpu it was merely 600 gs.

The problems of phosphate and potash fertilizations has been neglected by most of the citrus growers. However, the allocation of ammonium phosphate by the government in recent years that are welcomed by the growers are supply considerable amount of phosphate to orchards. The use of chemical potash fertilizer is still restricted to a few growers, consequently the supply of potash may mostly come from night soil and compost which are conventionally used.

The plot received trace elements, i. e. Zn, Mn, Mg in addition to N, P, K, had negligible effect in comparison with the check plot. The application of magnesium, calcium or trace elements in orchards are a common practice in foreign countries especially for Zn, Mn, and Mg (8). In some Taiwan orchards, the chrosis caused by nutrient deficiencies actually occur. Some symptoms had certain points of likeness to mottle leaves of zinc deficiency have been observed by the authors. Therefore the occurrence of trace element or secondary element deficiencies in Taiwan orchards seem to be possible. In spite of the fact, no these elements other than N, P, K are conventionally applied as fertilizers in local orchards. However, soil dressing that is made after harvesting biyearly or triyearly by some skilful growers acts an important role in citrus cultivation. The beneficial effect of soil dressing might have been partially due to the increase of some nutrients other than N, P, K. It may be attributed

to the soil dressing that traceelements are ineffective in those experimental orchards. The growers have conducted this practice in preceeding years in those orchards.

Effects on Nutrient Contents in Leaves

Extensive studies on the foliar diagnosis in estimating the fertility status of soils and nutritional requirements of crops have been made by many workers[9]. They have shown that the leaf analysis was a valuable aid for diagnosing deficiency or excess of the nutrient elements. These chemical studies have been directed more and more toward assigning a significance to the various levels of nutrient elements in plants as they relate to sick and healthy plants.

Some studies on pineapple[10,11], tea[12], rice[13] concering foliar diagmonsis were reported in Taiwan although leaf analysis was not yet used successfully in making more effective fertilizer recommendations. Leaf analysis of citrus[14] was also conducted in Taiwan but not for diagnosis purpose. In foreign countries the suceessful result of leaf analysis on citrus was obtained and its value was being recognized by growers not only as a means of identifying nutritional troubles in citrus, but as a means of knowing their nutritional status so that serious deficiencies can be prevented.

The present paper reports the results of preliminary studies on the citrus leaf diagnosis regarding the relation of the nutrients contents in leaves to the fertilizer treatments and times of sampling. All leaf analyses were made duplicate and all the percentage were reported in a moisture free basis. The data are shown in Table 12, in which the following observation were made.

According to the statistical analysis, the effect of treatment on the nitrogen content of citrus leaves was found to be significant; the leaves of the no nitrogen plot were generally low in total nitrogen content as compared with that of the complete fertilizer plot or other treatment plots. It was also found that the leaves of the no phosphorus plot were also somewhat low in P content at Taping locality, but other

Table 12a. Effects of fertilizer treatments and time of sampling on the nitrogen contents in citrus leaves (mean N %)

Locality	Time of sampling / Treatment	PK	NK	NP	NPK	NPK + T. E.	Average	L. S. D.
Chawmen	March	2.78	2.98	2.74	2.88	2.86	2.85	Among times of sampling** 5% 0.10 1% 0.13 Interaction: time × treatment,* 5% 0.693
	May	2.97	3.43	3.33	3.41	3.39	3.30	
	June	2.51	3.14	3.30	3.23	3.32	3.10	
	August	2.72	3.23	3.16	3.11	3.24	3.09	
	November	2.77	3.10	3.07	3.09	3.16	3.03	
	Average	2.75	3.17	3.12	3.14	3.19	3.07	
	L. S. D. Among fertilizer treatments ** 5% 0.10 1% 0.13							

Taping	March	2.68	2.75	2.35	2.44	2.46	2.53	Among times of sampling** 5% 0.12 1% 0.17 Interaction: time ×treatment, N.S.
	May	2.80	3.00	2.88	3.01	2.76	2.89	
	June	2.84	3.17	3.05	3.10	2.92	3.01	
	August	2.81	3.29	3.15	3.40	2.86	3.10	
	November	2.98	3.02	3.16	3.13	2.94	3.04	
	Average	2.82	3.04	2.91	3.01	2.78	2.91	
	L. S. D. Among fertilizer treatment ** 5% 0.12 1% 0.17							
Yuanlin	March	2.88	2.85	2.75	2.88	2.90	2.85	Among times of sampling** 5% 0.09 1% 0.12 Interaction: time ×treatment, N.S.
	May	3.23	3.18	3.21	3.28	3.25	3.23	
	June	3.09	3.26	3.17	3.24	3.19	3.19	
	August	2.98	3.07	3.06	2.95	3.09	3.03	
	November	3.20	3.22	3.03	3.19	3.01	3.12	
	Average	3.07	3.11	3.04	3.11	3.08	3.08	
	L. S. D. Among fertilizer treatment N. S.							

experimental localities showed evidently no offect of fertilizer treatment on the P content in leaves. The effect of fertilizer treatment on the K content in leaves has not caused significant. It is expected that the significant effect of each fertilizer treatment on leaf composition may be brought about after a somewhat longer term of experiment.

Table 12b. Effects of tertilizer treatments and time of sampling on the phosphorus contents in citrus leaves (mean P %)

Locality	Time of sampling/Treatment	PK	NK	NP	NPK	NPK + T. E.	Average	L. S. D.
Chawmen	March	0.155	0.155	0.153	0.150	0.162	0.155	Among times,** 5% 0.011 1% 0.015 Interaction: time ×treatment, N.S.
	May	0.202	0.196	0.189	0.177	0.183	0.189	
	June	0.183	0.180	0.159	0.163	0.168	0.170	
	August	0.156	0.146	0.142	0.148	0.157	0.150	
	November	0.152	0.154	0.160	0.151	0.165	0.156	
	Average	0.169	0.166	0.160	0.158	0.167	0.164	
	L. S. D. Among treatments, N. S.							
Taping	March	0.146	0.146	0.151	0.141	0.153	0.148	Among times,** 5% 0.008 1% 0.011 Interaction: time ×treatment, N.S.
	May	0.208	0.198	0.207	0.204	0.210	0.205	
	June	0.171	0.161	0.159	0.158	0.155	0.161	
	August	0.152	0.136	0.152	0.147	0.149	0.147	
	November	0.176	0.150	0.167	0.155	0.165	0.162	
	Average	0.170	0.158	0.167	0.161	0.166	0.164	
	L. S. D. Among treatment,* 5% 0.008							

Yuanlin	March	0.154	0.148	0.144	0.154	0.148	0.149	Among times,** 5% 0.0063 1% 0.0085 Interaction: time ×treatmnet, N.S.
	May	0.176	0.173	0.185	0.177	0.174	0.177	
	June	0.143	0.144	0.142	0.144	0.143	0.143	
	August	0.136	0.136	0.137	0.136	0.143	0.137	
	November	0.182	0.165	0.173	0.162	0.166	0.169	
	Average	0.158	0.153	0.156	0.154	0.154	0.155	
	L. S. D. Among treatments, N. S.							

Table 12c. Effects of fertilizer treatments and time of sampling on the potassium contents in citrus leaves (mean K %)

Locality	Time of asmpling / Treatment	PN	NK	NP	NPK	NPK T. E. +	Average	L. S. D.
Chawmen	March	0.86	0.93	0.96	0.91	0.95	0.93	Among times.** 5% 0.067 1% 0.091 Interaction: texture × treatment, N. S.
	May	1.19	1.24	1.19	1.16	1.08	1.17	
	June	1.21	1.16	1.22	1.47	1.39	1.29	
	August	1.11	1.02	0.99	1.06	0.94	1.03	
	November	0.94	0.85	0.80	0.87	0.84	0.90	
	Average	1.06	1.04	1.03	1.09	1.04	1.05	
	L. S. D. Among treatments, N. S.							
Taping	March	0.60	0.64	0.56	0.70	0.68	0.64	Among times,** 5% 0.113 1% 0.152 Interaction: time ×treatment, N.S.
	May	0.86	0.86	0.80	0.81	0.92	0.84	
	June	0.95	0.81	0.89	0.84	0.88	0.87	
	August	0.91	0.79	0.88	0.92	0.94	0.89	
	November	0.74	0.69	0.69	0.60	0.58	0.66	
	Average	0.80	0.76	0.76	0.78	0.80	0.78	
	L. S. D. Among treatments, N. S.							
Yuanlin	March	1.04	0.99	0.94	1.01	0.93	0.98	Among times,* 5% 0.138 Interaction: time ×treatment, N.S.
	May	1.15	1.02	1.29	1.16	1.04	1.14	
	June	1.29	1.34	1.18	1.10	1.10	1.20	
	August	1.10	1.07	1.10	1.01	0.95	1.04	
	November	1.28	1.16	1.14	1.00	1.04	1.12	
	Average	1.17	1.12	1.13	1.05	1.01	1.10	
	L. S. D. Among treatments, N. S.							

In this study, leaf sampling were taken five times in the following months, March, May, June, August and November. The Table 12 reveals that the effects of sampling time on the nutrient contents in leaves are apparent at all the experimental localities. In general, the N, P, K contents in leaves were high in May and June, then

decreased gradually and became minimum in March though there were some exceptions. The samples taken in March were old leaves and those taken in May were newly-matured, so that the trend mentioned above would be responsible to the age of citrus leaves.

SUMMARY

Field experiments on the fertilizer application in citrus orchards have been conducted in Sinpu and Yuanlin, the ponkan producing centers, since January, 1958. Five treatments i.e., a) PK, b) NK, c) NP, d) NPK, e) NPK+Mg, Mn, Zn, were replicated four or five times in a randomized block layout to determine the effect of three elements as well as the trace elements upon fruit yields and the nutrient contents of leaves. The amounts of fertilizers dressed were based on the conventional application of the local farmers, and ammonium sulphate, calcium phosphate and potassium chloride were used as N, P, K sources respectively.

Fruit yields and their number were recorded. Leaves were sampled five times in a year. The results obtained in the first year trial are as follows:

1. Nitrogen would be expected as the most essential element affecting fruityields and potash came to the next. The effect of phosphate was still unapparent. The average fruit yields per tree in the three localities and their indices were calculated as follows; a) PK 35.5kgs (81), b) NK 46.8kgs (106), c) NP 36.6kgs (83), d) NPK 44kgs (100), e) NPK+T. E. 43,7kgs (99).

2. The effects of fertilizers upon the weight of unit fruit was not so apparent in those orchards except in Yuanlin where the fruit size was somewhat decreased by the unfertilization of nitrogen. However, the fruit size was differed greatly among these localities, e. g. the mean weight per fruit in Chawmen and Taping were 184 gs and 160 gs respectively, while that in Yuanlin reached 229 gs. The difference might be rather du to the water content in soils than the tree age.

3. The trace element plot had negligible effect in comparison with that of the check plot. It is expected that the detection of significant effects of trace elements may need a long term experiment. Some symptoms of trace element deficiciencies occuring in other orchards seems to justify the necessity of trace elements apart from this experimental result.

4. The N, P, K contents in the leaf samples taken from all the experimental plots at different seasons were analyzed and it was found that the leaves in the no nitrogen plot were generally low in total nitrogen content.

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柑桔園施肥試驗（第一報）

邱再發　連　深　徐水泉

摘　　要

本試驗始於民國47年1月，目的在探討肥料三要素與微量元素對於柑桔收量之影響，以明瞭肥料三要素之施用比率及微量元素之缺否。同時亦經分析各肥料處理之柑葉樣本以供將來葉部診斷法研究之參考。

田間設計採用逢機區集法 4～5 重覆，每小區由 4棵柑桔樹所成。試驗地點共設三處，其中兩處屬新埔鎮其樹齡爲18年及20年，另一處則屬員林鎮其樹齡爲 9年，其品種皆爲椪柑。第一年所得結果簡列如次。

（1） 三要素中以氮肥對柑桔收量之影響最大。鉀肥則次之，磷肥尚無明顯效果。各處理區平均每棵樹之果實收量及其指數如次：

每棵樹果實平均產量 （公斤）

處理＼地點	照　門	大　坪	員　林	平　均	指　數
a) 無 氮 區 (PK)	56.12	21.92	28.41	35.48	81
b) 無 磷 區 (NK)	69.49	28.58	42.48	46.85	106
c) 無 鉀 區 (NP)	57.97	18.28	33.58	36.62	83
d) 對 照 區 (NPK)	62.79	25.60	43.64	44.01	100
e) 微量元數區 (NPK+T.E.)	63.83	27.57	39.73	43.71	99

（2） 各種肥料處理對於單位果實重量之影響甚小，惟各地之平均果實重量則相差甚多，如新埔地區每粒重量爲照門 184g 大坪 160g 而員林則高達 229g。除柑樹年齡之外此必與土壤水分含量之多寡有關。

（3） 微量元素缺乏症狀曾見於新埔各地，惟本試驗所設微量元素區却尚無任何增收之效果。

（4） 由柑葉分析結果知無氮區柑葉所含全氮量顯然因不施氮肥而降低，於磷鉀含量則尚無處理間之明顯差異。因柑葉之新舊有別，故季節對於三要素含量之影響較大。